COMPARATIVE INFLUENCES OF ENVIRONMENTAL PARAMETERS ON ABUNDANCES OF HYBRID STRIPED BASS AND WHITE BASS IN THE GRAND LAKE TAILWATER, OKLAHOMA

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INTRODUCTION

This thesis is comprised of one manuscript written for submission to the Transactions of the American Fisheries Society. Chapter I is an introduction to the rest of the thesis. The manuscript is complete as written and does not require additional support material. The manuscript is contained in Chapter II and is titled 'Comparative influences of environmental parameters on abundances of hybrid striped bass and white bass in the Grand Lake tailwater, Oklahoma.'

Chapter II

COMPARATIVE INFLUENCES OF ENVIRONMENTAL PARAMETERS ON ABUNDANCES OF HYBRID STRIPED BASS AND WHITE BASS IN THE GRAND LAKE TAILWATER, OKLAHOMA

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Abstract.-I sampled hybrid striped bass and white bass in the Pensacola Dam tailwater of Grand Lake, Oklahoma, using gill nets at monthly intervals from January 1988 to July 1989 to determine relationships between relative abundances of hybrids and white bass and changes in water temperature, dissolved oxygen concentration, water discharge, and photoperiod. Distance from the dam was also included to assess fish concentration in the stilling basin. Water quality parameters were recorded concurrently. Unimodal response curves related to water temperature and photoperiod were linearized using natural logarithms and absolute deviations from spawning temperatures and selected photoperiod intervals. All response profiles were logarithmically transformed and analyzed using Pearson correlations; analyses of covariance were used to compare responses between hybrids and white bass for each parameter. Multiple-regression models were formulated to examine influences of these variables on fish abundances. Hybrids and white bass apparently initiated spawning migrations into the tailwater during spring and dispersed into downstream reaches after the spawning season. Hybrid and white bass catch-per-unit-effort (CPUE) rates were most influenced by month-long water discharge and water temperature, respectively. Photoperiod and distance from the dam were less influential; dissolved oxygen concentration had no significant overall effect on CPUE rates. Reduced summer discharges drawn from the cool hypolimnion of Grand Lake

degrade the suitability of the tailwater compared to downstream areas. Elevated, consistent discharges drawn from the warmer epilimnion probably would enhance summer abundances of hybrids and white bass in the tailwater.

INTRODUCTION

Hybrid striped bass (hereafter referred to as "hybrids") were successfully produced in 1965 by crossing female striped bass (Morone saxatilis) with male white bass (M. chrysops); the reciprocal cross was also attempted, but survival of fry was poor (Bishop 1967). Hybrids have higher survival rates than striped bass (Bishop 1967; Logan 1967; Bayless 1972; Ware 1974; Axon and Whitehurst 1985), generally grow faster than striped bass (Logan 1967; Bayless 1972; Ware 1974), and are also hard-fighting game fish with palatable flesh (Bishop 1967). The stocking of hybrids is generally economical, with favorable cost-benefit ratios (Crandall 1979; Moss and Lawson 1982). Consequently, hybrids are popular with anglers and managers and are often stocked in bodies of water where striped bass would not survive.

A total of 12,100,000 striped bass fry were introduced into Grand Lake O' the Cherokees (Grand Lake), Oklahoma, from 1973 through 1978 (Smith 1986). Few of these fry survived to the adult stage. Apparently, the environmental conditions present in the lake were not conducive to striped bass survival. Consequently, stocking of hybrids in Grand Lake began in 1981. Some of these escaped over the Pensacola Dam spillway into the Neosho River, and a popular fishery for hybrids became established in the tailwater of

Grand Lake. Hybrids are also present in Lake Hudson, 22.5 km downriver from Grand Lake.

Because development of hybrids is relatively recent, research on this fish is limited. Information about their feeding habits and environmental (i.e., water quality) tolerances and preferences can be critical to management specialists, especially in areas where hybrids have spread beyond their intended ranges.

Seasonal dynamics of hybrid abundances in tailwater areas are poorly known. Previous studies indicated that water temperature, photoperiod, and water discharge were associated with hybrid migrations into spawning areas (Williams 1970; Muncy et al. 1990). The influence of dissolved oxygen concentration on hybrid abundances in tailwater areas has not been analyzed, but lacustrine studies indicated habitat selection by hybrids based on dissolved oxygen concentration as well as water temperature (Yeager 1982; Douglas and Jahn 1987; Phalen et al. 1990). No other information is available regarding the influences of water temperature, dissolved oxygen concentration, water discharge, or photoperiod on hybrid abundances in tailwater areas.

Tailwater angling for hybrids has become popular in locations where hybrid stocking programs exist, such as at Grand Lake; however, lack of knowledge regarding environmental preferences of hybrids precludes effective management. Because hybrids exist in the Grand Lake tailwater along with white bass, this tailwater afforded the possibility to examine the potential influences of water temperature, dissolved oxygen concentration, water discharge, and photoperiod on the abundances of hybrids and white bass. Furthermore, because hybrids and white bass were exposed to the same set of parameters, their responses could be compared.

STUDY SITE

The study site was the tailwater area of the Pensacola Dam of Grand Lake, a 18,818-hectare lake formed by the impoundment of the Neosho River in northeast Oklahoma. Water used for hydropower generation was drawn from Grand Lake through a fixed intake located about 13 m below the surface. The minimum and maximum discharge rates for effective power generation at the hydropower facility were 28 and 340 m^3/s, respectively. Unlike most hydropower installations, floodwater discharged over the spillway did not empty directly into the tailwater; rather, it drained into the Neosho River about 2 km below the tailwater. The sampling area extended from the turbine outlet structure to the power station access bridge (Figure 1). This area was about 950 m long and 120 m wide. Water depth during sampling graduated from < 1 m near the upper end to 2.5 m at the lower end; an irregular trough about 3 m deep (the stilling basin) was situated under the turbine outlets.

METHODS

Field techniques

Sampling was conducted with experimental gill nets during daylight hours at about monthly intervals from January 1988 through July 1989. No turbine discharge occurred during sampling to prevent net displacement. The site was divided into 26 stations of about 42x100 m (Figure 1); 24 stations were arranged into two shoreline columns and a midchannel column. The stilling basin above the boat-excluding cable was divided into two stations. Each row of stations was numbered consecutively to represent distance from the dam, beginning with the stilling basin stations.

The monofilament-nylon gill nets had six 15.2-m panels with bar mesh sizes of 3.81, 5.08, 6.35, 7.62, 8.89, and 10.16 cm. The nets were 2.4 m deep and 91.4 m long. A gill net was deployed for a two-hour interval in each of seven stations and retrieved. Net placement was determined using a randomly-stratified design on each sampling date. Two nets were set in stations in each of the three columns. The seventh net was randomly set in one of the two stilling basin stations. All nets were set parallel to shore. All hybrids and white bass collected were weighed (g), measured (mm total length), and released. Size, coloration, and tooth patches were used to differentiate hybrids from white bass (Bishop 1967; Williams 1975). To minimize the possibility of recording fish captured more than once on each sampling date, all hybrids and white bass with missing scales or fresh net marks were not counted.

Water temperature and dissolved oxygen concentration were recorded concurrently with fish sampling using a Hydrolab Surveyor II (Hydrolab Corporation, Austin, Texas). Readings were taken at a depth of 1 m at water quality stations located at the cable, opposite the boat ramp, and under the bridge (Figure 1); means of readings for each sampling date were used in all analyses. Water discharge records were acquired from the Grand River Dam Authority (GRDA). Photoperiod data were acquired from the Oklahoma City branch of the National Weather Bureau. Because hybrids and white bass concentrate in stilling basins during their upstream migration (Walburg et al. 1971), distance from the dam was included as a parameter in all analyses.

Analyses

Hourly gill net catch-per-unit-effort (CPUE) rate for each net set was calculated using the following formula:

$$CPUE = \ln[(N/t)*60]$$

where N = number of hybrids or white bass caught and t = number of minutes the net was deployed. CPUE rates were assigned a value of 0.1 if no hybrids or white bass were caught in a net set to permit logarithmic transformation.

Relationships between CPUE rates of hybrids and white bass and water temperature, dissolved oxygen concentration, photoperiod, distance from the dam, and water discharge (total of daily discharges for one, two, four, seven, fourteen, and twenty-eight days prior to each sampling date) were examined using correlation analyses. To transform the curvilinear (i.e., bell-shaped) relationships between CPUE rates and water temperatures in the sampling area, temperature data were converted using the following formula:

$$T_t = |T_o - T_s|$$

where T_t was transformed water temperature, T_o was observed water temperature, and T_s was spawning water temperature of hybrids or white bass. Because spawning migrations into the tailwater probably influenced hybrid and white bass CPUE rates, a range of water temperatures encompassing known migration temperatures of hybrids (Williams 1970) and white bass (Webb and Moss 1967; Ruelle 1971; Hamilton and Nelson 1984) were used to transform temperature data. This conversion resulted in the folding of the left-hand arc of the curve onto the right-hand arc, forming a general linear model with the selected temperature as the origin of the x-axis; because the model was no longer curvilinear, analysis was simplified. Converted data sets were then tested for significance of association with each respective selected temperature using correlation analyses; all data sets with significant correlations were used for further analysis. The data set with the strongest significant correlation generally indicated a peak in the normal distribution at the relevant selected temperature; this indicator was similar to the preference curves produced by Gore and Judy (1981). Photoperiod data were similarly converted, but because recognized ideal photoperiod values do not exist, 'ideal' values were determined, based on goodness-of-fit using correlation analyses, within the range of 550 to 900 min at 25-min intervals. This range encompassed minimum and maximum photoperiod intervals encountered during the sampling period.

Analysis of covariance (ANCOVA) was used to determine if significant differences existed between relationships between hybrid and white bass CPUE rates and each independent variable.

Stepwise multiple regression analyses were performed to determine relationships between hybrid and white bass CPUE rates and all transformed and nontransformed variables, and to rank each variable in terms of influence on CPUE rates. Because multiple spawning temperatures and photoperiod intervals were used during conversion, a series of transformed data sets existed, one for each selected spawning temperature or photoperiod interval. As a result, regression analyses were done for all possible combinations with CPUE rates of water discharge, dissolved oxygen concentration, distance from the dam, and all transformed data sets of water temperature and photoperiod. Because of the large numeric differences between water discharge values and CPUE values, all water discharge values were divided by 100,000 to generate discernible parameter estimates in stepwise models. All variables were also entered in the models as squares, cubes, square roots, and cube roots to determine if elements of curvilinearity existed or remained after conversion. All analyses were performed with Statistical Analysis System procedures (SAS Institute 1985, 1988).

RESULTS

More than three times as many white bass were caught than hybrids (Table 1); consequently, CPUE rates were generally higher for white bass than for hybrids, and this phenomenon was reflected in comparative analyses. CPUE rates for hybrids peaked in spring and generally declined through summer, autumn, and winter; white bass CPUE rates exhibited a similar trend, but with a slight resurgence during late fall and early winter (Figure 2).

Water temperature

Hybrid CPUE rates were significantly correlated with absolute temperature deviations based on spawning temperatures of 14 and 15°C (Table 2). The stronger association existed relative to deviations from 15°C ($r^2 = -0.195$). White bass CPUE rates were significantly correlated with absolute temperature deviations based on spawning temperatures ranging from 10 to 20°C (Table 2). The strongest association existed relative to deviations from 13°C ($r^2 = -0.482$).

Significant differences existed between slopes of the relationships between hybrid and white bass CPUE rates and absolute temperature deviations at 14°C (ANCOVA: $F = 11.30$; $df = 1, 251$; $P < 0.01$) and at 15°C ($F = 8.92$, $df = 1, 251$; $P < 0.01$). Slopes associated with white bass CPUE rates were significantly greater (larger negative coefficients) than those associated with hybrid CPUE rates.

Dissolved Oxygen Concentration

No significant correlations existed between hybrid or white bass CPUE rates and dissolved oxygen concentrations.

Photoperiod

Hybrid CPUE rates were significantly correlated with absolute deviation values based on photoperiod intervals of 775-875 min of daylight (Table 3); the strongest association existed relative to deviations from 825 min ($r^2 = -0.222$). White bass CPUE rates were also significantly correlated with absolute deviation values based on photoperiod intervals of 775-875 min of daylight (Table 3); the strongest association existed relative to deviations from 800 min ($r^2 = -0.326$).

No significant differences existed between slopes of the relationships between hybrid and white bass CPUE rates and absolute photoperiod interval deviations from 775 min (ANCOVA: $F = 1.62$; df = 1, 251; $P > 0.20$), 800 min ($F = 2.66$; Df = 1, 251; $P > 0.10$), 825 min ($F = 2.02$; df = 1, 251; $P > 0.16$), 850 min ($F = 1.58$; df = 1, 251; $P > 0.21$), and 875 min of daylight ($F = 1.53$; df = 1, 251; $P > 0.22$). However, significant differences existed between intercepts of these photoperiod regressions: 775 min (ANCOVA: $F = 8.37$; df = 1, 251; $P < 0.01$); 800 min ($F = 8.60$; df = 1, 251; P <

0.01); 825 min (F = 8.58; df = 1, 251; $P < 0.01$); 850 min (F = 8.41; df = 1, 251; $P < 0.01$); and 875 min of daylight (F = 8.37; df = 1, 251; $P < 0.01$). Intercepts associated with white bass CPUE regressions were higher than those associated with hybrid CPUE rates.

Distance from the Dam

Hybrid and white bass CPUE rates were inversely correlated with distance from the dam (hybrids: $r^2 = -0.212$; P = 0.017; white bass: $r^2 = -0.225$; P = 0.011). No significant differences existed between slopes of the relationships between hybrid and white bass CPUE rates and distance from the dam (ANCOVA: F = 0.44; df = 1, 251; $P > 0.51$). However, significant differences existed between intercepts (ANCOVA: F = 8.35; df = 1, 251; $P < 0.01$). Intercepts associated with white bass CPUE regressions were higher than those associated with hybrid CPUE rates.

Water Discharge

Hybrid CPUE rates were significantly correlated with total water discharges over the intervals of 4, 7, 14, and 28 days prior to each sampling date (Table 4); the strongest correlation existed relative to intervals of 28 days ($r^2 = 0.451$). No significant correlations existed between white bass CPUE rates and total water discharges over any interval (Table 4), but the correlation relative to intervals of 28 days approached significance (P = 0.081).

Stepwise Multiple-Regression Analyses

Multiple-regression models for hybrid and white bass CPUE rates and environmental variables accounted for 40% and 43% of the variance, respectively (Table 5). Hybrid abundances were negatively correlated with absolute deviations from a water temperature of 16°C, absolute deviations from a photoperiod interval of 850 min of daylight, and distance from the dam; hybrid CPUE rates were positively correlated with total water discharge intervals of 28 days prior to each sampling date. Standardized partial regression coefficients suggested that total water discharge of 28-day intervals had the greatest influence on hybrid CPUE rates, followed by water temperature, photoperiod, and distance from the dam (Table 5).

White bass abundances were negatively correlated with absolute deviations from a water temperature of 13°C, absolute deviations from a photoperiod interval of 800 min of daylight, and distance from the dam; white bass CPUE rates were positively correlated with total water discharge intervals of 28 days prior to each sampling date. Standardized partial regression coefficients indicated that water temperature had the greatest influence on white bass CPUE rates, followed by photoperiod, distance from the dam, and total water discharge of 28-day intervals (Table 5).

All models and variables within both models were significant ($P < 0.01$). No powers or roots appeared in any model, confirming that no curvilinear relationships remained between independent variables and CPUE rates after the transformations were performed.

DISCUSSION

Previous studies indicated that water temperature, dissolved oxygen concentration, water flow, and spawning cycles influenced abundances of fish in tailwaters (Eschmeyer and Smith 1943; Eschmeyer 1944; Hanson 1977; Edwards 1978; Newcombe 1981; Ruane et al. 1986; Jackson and Davies 1988a; Muncy et al. 1990). The most influential factors affecting hybrid and white bass CPUE rates below Pensacola Dam were water discharge and water temperature, respectively; distance from the dam and photoperiod also had significant influences. These findings probably reflect the effects of environmental conditions on spawning migrations during spring; although similar environmental conditions existed during autumn, white bass and especially hybrids were abundant only in spring. Conditions during spring induced migrations into the tailwater; further upstream progress was blocked by the presence of the dam, which caused concentration of fish in the tailwater (Walburg et al. 1971). Conditions during summer compelled fish to seek preferred habitats and water quality conditions downstream, where they remained despite spring-like conditions in the tailwater during autumn. The discrepancy between spring and autumn hybrid and white bass CPUE rates in the tailwater, in the absence of differences in water quality, weakened the statistical relationships.

A concurrent study carried out in 1988 (Zale et al.

1990) indicated that hybrid and white bass abundances in the headwaters of Lake Hudson peaked earlier in spring than in the Pensacola Dam tailwater. White bass abundances in Hudson increased during summer, concurrent with the decrease in tailwater abundances; a minor peak in tailwater abundances occurred in late autumn, but abundances in Hudson fluctuated at moderate levels throughout autumn and winter. Hybrids were caught in the Hudson headwaters only during spring. Apparently, hybrids and white bass moved through the Hudson headwaters during their upstream spring migration from the main body of Lake Hudson into the Pensacola Dam tailwater; after the spawning season, they retreated through the headwaters back into Lake Hudson.

White bass CPUE rates peaked at lower water temperatures (13^{o}C) than hybrid CPUE rates (15^{o}C). Previous studies indicated that white bass initiated spawning migrations at temperatures of 12-14^{o}C (Webb and Moss 1967; Ruelle 1971; Hamilton and Nelson 1984), whereas the range of optimum spawning temperatures of striped bass was 17 to 20^{o}C (McCoy 1959; Shannon and Smith 1968; Crance 1984). Accordingly, peak abundances of hybrids were associated with temperatures intermediate between those associated with spawning temperatures of white bass and of striped bass. However, hybrids were more abundant than white bass in the sampling area during January and February of 1988, suggesting that migration of hybrids into the tailwater area began earlier than migration of white bass. This corresponded with the observations of Williams (1970). In 1989, hybrids first appeared in the sampling nets about the same time as white bass. The association of white bass CPUE rates with cooler water temperatures may have been caused by the presence of white bass in the tailwater in late autumn and early winter in 1988. Water temperatures during this period were equal to or lower than spring temperatures; this probably caused a shift in correlations towards lower water temperatures. Hybrids were present in the tailwater in early autumn of 1988, but the number caught probably was not large enough to significantly affect analyses. Both hybrids and white bass were present in the tailwater in early summer of 1988, but hybrid CPUE rates decreased more rapidly than white bass CPUE rates during summer as a result of downstream movement first by hybrids and then by white bass. Summer water temperature preferences of white bass are higher (Jester 1971; Gammon 1973; Kohler and Ney 1981; Hamilton and Nelson 1984) than those of hybrids (Douglas and Jahn 1987; Phalen et al. 1990); some white bass may have lingered in the tailwater through summer despite decreasing dissolved oxygen concentrations. Furthermore, hypolimnetic discharges into the tailwater did not cause large fluctuations in water temperature over short periods and thereby precluded temperature shock stress. Despite favorable water quality conditions in the tailwater during autumn, hybrids generally remained downstream, where preferred conditions apparently were available.

The majority of hybrids and white bass in the tailwater during spring were sexually mature, whereas autumn assemblages were composed mostly of sexually immature juveniles, as judged by sizes at maturity in the literature (Howell 1945; Bishop 1967; Webb and Moss 1967; Germann and Bunch 1982; Hamilton and Nelson 1984). Accordingly, reduced activity, caused by cessation of production of hormones governing spawning migrations (i.e., the refractory reproductive phase; Liley 1969), may have also contributed to the resistance of sexually mature fish to upstream movement during autumn.

Hybrids tolerate dissolved oxygen levels as low as 2 mg/L (Douglas and Jahn 1987) to 4 mg/L (Phalen et al. 1990). White bass ceased to feed and became relatively inactive at dissolved oxygen concentrations < 3 mg/L (Mount 1961). Dissolved oxygen concentrations in the Pensacola Dam tailwater did not fall below about 3 mg/L. Hybrid and white bass CPUE rates declined through summer concurrent with decreasing dissolved oxygen concentrations but remained low in autumn despite improved dissolved oxygen concentrations; apparently, more favorable dissolved oxygen concentrations were available downstream, and white bass and especially hybrids resisted movement back into the tailwater. Consequently, dissolved oxygen concentration appeared to have minimal overall influence on hybrid and white bass abundances in this tailwater.

Photoperiod had a moderate influence on hybrid and white bass CPUE rates. White bass CPUE rates peaked at a shorter photoperiod interval than hybrid CPUE rates. However, correlations associated with white bass CPUE rates may have been skewed towards shorter photoperiod intervals because of the minor peak in white bass abundances during late autumn and early winter when photoperiod intervals were shorter than during spring spawning migrations. Consequently, differences between associations between photoperiod and hybrid and white bass CPUE rates may not have been significant.

The negative association between distance from the dam and hybrid and white bass CPUE rates suggested that hybrids and white bass concentrated in the stilling basin. Over half of the hybrids and white bass were caught in the basin, perhaps because the presence of the dam prevented fish from ascending farther upstream (Walburg et al. 1971). Concentrations of forage fish in the stilling basin also may have contributed to the enhanced abundances of hybrids and white bass there.

The strength of the correlations between hybrid CPUE rates and total water discharge increased as the length of the water discharge interval increased. Fluctuations in water discharge in the tailwater were relatively less pronounced by month than by day; this suggested that hybrids were relatively unresponsive to short-term changes in water discharge, but were strongly influenced by long-term discharges, especially prior to spawning migrations during spring. The absence of significant correlations between white bass CPUE rates and discharge intervals indicated that white bass were unaffected by fluctuations in water discharge. Although water discharges were higher during spring of 1988 than during spring of 1989, more than twice as many white bass were caught during this period in 1989 than in 1988; hybrid CPUE rates exhibited the reverse.

Stepwise multiple-regression models accounted for less than half of the variance in hybrid and white bass CPUE rates. Informal models constructed to examine variance using only stilling basin data indicated higher R^2 values for hybrids (0.53) and for white bass (0.85). This suggested that uneven spatial distribution of fish in the rest of the sampling area contributed to the unexplained portion of variance within models; however, the small sample sizes (N = 18) associated with these data precluded definitive analysis. Furthermore, the relative scarcity of hybrids and, to a lesser degree, white bass in the tailwater during autumn despite moderate water temperatures and dissolved oxygen concentrations could have contributed to the unexplained portion of the variance within models.

Striped bass prefer water temperatures of 16-20°C for spawning (McCoy 1959; Shannon and Smith 1968; Combs 1977; Crance 1984); hybrids exhibited a preference for temperatures below this range, within the preferred range of white bass, both in this study and in others (Ruelle 1971; Hamilton and Nelson 1984). Comparisons with striped bass preferences regarding water discharge and photoperiod were not possible due to lack of information regarding the influences of these variables on striped bass abundances in tailwater areas similar to the Pensacola Dam tailwater. However, in a recent study on factors affecting reproductive success of striped bass in the Arkansas River, Oklahoma, photoperiod had a significant influence on striped bass egg abundances (Brian L. Bohnsack, Oklahoma Cooperative Fish & Wildlife Research Unit, personal communication), suggesting that spawning migrations of striped bass into tailwater areas may be influenced by photoperiod.

Management Implications

Because the Pensacola Dam tailwater is located in close proximity to a downstream reservoir, does not directly receive spillway discharges, and has a small, narrow stilling basin, hybrids and white bass probably migrate into the tailwater area only during the spawning season and seek thermal refuges downstream during the remainder of the year. Typical Oklahoma tailwaters are situated above long, shallow rivers and offer large, deep stilling basins with direct, aerated spillway discharges; these tailwaters sustain fish assemblages throughout much of the year. As a result, management opportunities suggested by hybrid and white bass CPUE models in this study may not be applicable to a wide range of situations existing in tailwater areas. However, any strategy applied to management of hybrids and white bass in the Pensacola Dam tailwater needs to address the problem of fish dispersal into downstream reaches following the spawning season. Hybrid and white bass abundances were most influenced by water discharge and water temperature, respectively; consequently, low-volume discharges of cool, hypoxic water drawn from the hypolimnion of Grand Lake during summer degrade the suitability of the tailwater for habitation by these fishes. Alteration of the intake structure in the lake, perhaps with the addition of multilevel intakes, to produce elevated, consistent discharges of water drawn from the warm, better oxygenated epilimnion probably would enhance summer conditions in the tailwater. Mechanical destratification of the lake would produce a similar result if the summer thermocline could be kept below the level of the intake. Invertebrates (zooplankton and insects) are considered a primary source of energy supporting fisheries (Jackson and Davies 1988b); epilimnetic discharges probably would enhance zooplankton transport through the hydropower system (Walburg et al. 1971; Jackson and Davies 1988b) and improve summer forage opportunities in the tailwater. Other methods for improving summer conditions in the tailwater include in-turbine and tailrace aeration and direct spillway discharges. Any alteration of the hydropower system at Grand Lake would not likely be cost-effective; however, such methods could be economically feasible in other tailwater designs, both those existing and under development.

REFERENCES

Axon, J. R., and D. K. Whitehurst. 1985. Striped bass management in lakes with emphasis on management problems. Transactions of the American Fisheries Society 114:8-11.

Bayless, J. D. 1972. Artificial propagation and hybridization of striped bass, Morone saxatilis (Walbaum). South Carolina Wildlife and Marine Resources Department.

Bishop, R. David. 1967. Evaluation of the striped bass (Roccus saxatilis) and white bass (Morone chrysops) hybrids after two years. Proceedings of the Annual Conference of the Southeastern Association of Game and Fish Commissioners 21:245-253.

Combs, D. L. 1977. Striped bass spawning in the Arkansas River tributary of Keystone Reservoir, Oklahoma. Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies 33:371-383.

Crance, J. H. 1984. Habitat suitability index models and instream flow suitability curves: inland stocks of striped bass. Biological Report 82(10.85), U.S. Fish and Wildlife Service, Washington D.C.

Crandall, P. S. 1979. Evaluation of striped bass x white bass hybrids in a heated Texas reservoir. Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies 32:588-598.

Douglas, D. R., and L. A. Jahn. 1987. Radiotracking hybrid striped bass in Spring Lake, Illinois, to determine temperature and oxygen preferences. North American Journal of Fishery Management 7:531-534.

Eschmeyer, R. W., and C. G. Smith. 1943. Fish spawning below Norris Dam. Journal of the Tennessee Academy of Science 18:4-5.

Eschmeyer, R. W. 1944. Fish migration into the Clinch River below Norris Dam, Tennessee. Journal of the Tennessee Academy of Science 19:31-41.

Edwards, R. J. 1978. The effect of hypolimnion reservoir releases on fish distribution and species diversity. Transactions of the American Fisheries Society 107:71-77.

Gammon, J. R. 1973. The effect of thermal input on the populations of fish and macroinvertebrates in the Wabash River. Purdue University Water Research Center Technical Report 32, Lafayette, Indiana.

Germann, J. F., and Z. E. Bunch. 1982. Age, growth, and survival of <u>Morone</u> hybrids in Clarks Hill Reservoir, Georgia. Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies 37:267-275.

Gore, J. A., and R. D. Judy, Jr. 1981. Predictive models of benthic macroinvertebrate density for use in instream flow studies and regulated flow management. Canadian Journal of Fisheries and Aquatic Sciences 38:1363-1370.

Hamilton, K., and P. C. Nelson. 1984. Habitat suitability index models and instream flow suitability index curves: white bass. Biological Report 82(10.89), U.S. Fish and Wildlife Service, Washington, D.C.

Hanson, W. D. 1977. Tailwater fisheries of Lake of the Ozarks and Pomme de Terre Lake, Missouri. Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies 31:505-513.

Howell, H. H. 1945. The white bass in TVA waters. Journal of the Tennessee Academy of Science 20:41-48.

Jackson, D. C., and W. D. Davies. 1988a. Environmental factors influencing summer angler effort on the Jordan Dam tailwater, Alabama. North American Journal of Fisheries Management 8:305-309.

Jackson, D. C., and W. D. Davies. 1988b. The influence of differing flow regimes on the tailwater fishery below Jordan Dam , Alabama. Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies 40:37-46.

Jester, D. B. 1971. Effects of commercial fishing, species introductions, and drawdown control on fish populations in Elephant Butte Reservoir, New Mexico. Pages 265-285 <u>in</u> G. E. Hall, editor. Reservoir fisheries and limnology. American Fisheries Society Special Publication 8, Bethesda, Maryland.

Kohler, C. C., and J. J. Ney. 1981. Consequences of an alewife die-off to fish and zooplankton in a reservoir. Transactions of the American Fisheries Society 110:360-369.

Liley, N. R. 1969. Hormones and reproductive behavior in fishes. Pages 73-116 in W. S. Hoar and D. J. Randall, editors. Fish Physiology, volume 3. Academic Press, New York and London.

Logan, H. J. 1967. Comparison of growth and survival rates of striped bass and striped bass x white bass hybrids under controlled environments. Proceedings of the Annual Conference of the Southeastern Association of Game and Fish Commissioners 21:260-263.

McCoy, E. G. 1959. Quantitative sampling of striped bass, Roccus saxatilis (Walbaum), eggs in the Roanoake River, North Carolina. M.S. thesis, North Carolina State College, Raleigh.

Moss. J. L., and C. S. Lawson. 1982. Evaluation of striped bass and hybrid striped bass stockings in eight Alabama public fishing lakes. Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies 36:33-41.

Mount, D. I. 1961. Development of a system for controlling dissolved-oxygen content of water. Transactions of the American Fisheries Society 90:323-327.

Muncy, R. J., R. A. DeMauro, L. E. Miranda, and P. S. Phalen. 1990. Hybrid striped bass evaluations: Habitats used by radio-tagged adult hybrids in Ross Barnett Reservoir. Completion Report, Federal Aid to Fisheries Project F-82-1, Mississippi Cooperative Fish and Wildlife Research Unit, Mississippi State.

Newcombe, C. 1981. A procedure to estimate changes in fish populations caused by changes in stream discharge. Transactions of the American Fisheries Society 110:382-390.

Phalen, P. S., R. J. Muncy, and T. K. Cross. 1990. Hybrid striped bass movements and habitat in Ross Barnett Reservoir, Mississippi. Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies 42:35-43.

Ruane, R. J., C. E. Bohac, W. M. Seawell, and R. M. Shane. 1986. Improving the downstream environment by reservoir release modifications. Pages 270-277 <u>in</u> G. E. Hall and M. J. Van Den Avyle, editors. Reservoir Fisheries Management: Strategies for the 80's. Reservoir Committee, Southern Division of the American Fisheries Society, Bethesda, Maryland.

Ruelle, R. 1971. Factors influencing growth of white bass in Lewis and Clark Lake. Pages 411-424 <u>in</u> G. E. Hall, editor. Reservoir fisheries and limnology. American Fisheries Society Special Publication 8, Bethesda, Maryland.

SAS Institute, Inc. 1985. SAS User's Guide: Basics, Version 5 Edition. Cary, N.C.

SAS Institute, Inc. 1988. SAS/STAT Guide for Personal Computers, Version 6 Edition. Cary, N.C.

Shannon, E. H., and W. B. Smith. 1968. Preliminary observations on the effect of temperature on striped bass eggs and sac fry. Proceedings of the Southeastern Association of Game and Fish Commissioners 21:257-260.

Smith, J. 1986. Fish management survey and recommendations for Grand Lake. Survey Report, Oklahoma Fisheries Management Program. Federal Aid Project No. F-44-D-1.

Walburg, C. H., G. L. Kaiser, and P. L. Hudson. 1971. Lewis and Clark Lake tailwater biota and some relations of the tailwater and reservoir fish populations. Pages 449-467 in G. E. Hall, editor. Reservoir Fisheries and Limnology. American Fisheries Society Special Publication 8, Bethesda, Maryland.

Ware, F. J. 1974. Progress with Morone hybrids in freshwater. Proceedings of the Annual Conference of the Southeastern Association of Game and Fish Commissioners 28:48-54.

Webb, J. F., and D. D. Moss. 1967. Spawning behavior and growth of white bass in Center Hill Reservoir, Tennessee. Proceedings of the Annual Conference of the Southeastern Association of Game and Fish Commissioners 21:343-357.

Williams, H. M. 1970. Preliminary studies of certain aspects of the life history of the hybrid (striped bass x white bass) in two South Carolina reservoirs. Proceedings of the Annual Conference of the Southeastern Association of Game and Fish Commissioners 24:424-431.

Williams, H. M. 1975. Characteristics for distinguishing white bass, striped bass and their hybrid (striped bass x white bass). Proceedings of the Annual Conference of the Southeastern Association of Game and Fish Commissioners 29:168-172.

Yeager, D. M. 1982. Ultrasonic telemetry of striped bass x white bass hybrids in the Escambia River, Florida. Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies 36:62-73.

Zale, A. V., T. G. Adornato, and W. L. Fisher. 1990. Effects of the Pensacola hydropower project on the fishery resource of the Grand River. Component C. Effects on fisheries of establishment of a riverine environment in the headwaters of Lake Hudson. Final Report to the Grand River Dam Authority, Vinita, Oklahoma.

Table 1. Total catches (N), catch-per-unit-effort (CPUE) rates (number caught/hr), and standard deviations (SD) of nontransformed CPUE rates of hybrid striped bass and white bass caught with gill nets in the Pensacola Dam tailwater, Oklahoma, January 1988 to July 1989.

	Hybrid Striped Bass			White Bass		
Date	N	CPUE	SD	N	CPUE	SD
15 JAN 1988	3	0.107	0.134	1	0.036	0.094
4 FEB 1988	23	1.307	0.986	0	0.000	0.000
2 MAY 1988	147	6.117	8.152	132	6.007	4.995
24 MAY 1988	53	3.750	8.934	38	2.730	2.837
23 JUN 1988	6	0.387	0.691	11	0.712	0.875
21 JUL 1988	3	0.214	0.567	6	0.410	0.427
18 AUG 1988	0	0.000	0.000	4	0.248	0.556
17 SEP 1988	3	0.213	0.379	3	0.214	0.269
16 OCT 1988	1	0.080	0.212	3	0.232	0.434
19 NOV 1988	0	0.000	0.000	43	3.071	7.694
9 DEC 1988	1	0.071	0.189	26	1.848	4.700
29 JAN 1989	0	0.000	0.000	17	1.098	1.255
26 FEB 1989	0	0.000	0.000	1	0.075	0.197
11 MAR 1989	0	0.000	0.000	0	0.000	0.000
25 APR 1989	25	1.675	2.781	396	24.150	21.285
12 MAY 1989	4	0.881	1.756	150	9.858	24.981
9 JUN 1989	1	0.067	0.179	19	1.021	1.965
25 JUL 1989	1	0.063	0.167	0	0.000	0.000
TOTAL	271			850		

Table 2. Pearson product-moment correlations between natural logarithms of hybrid striped bass and white bass gill net CPUE rates (number caught/hour) and deviations from selected water temperatures in the Pensacola Dam tailwater, Oklahoma, January 1988 to July 1989. Asterisks denote statistically significant correlations ($P = 0.05$).

Temperature (^{o}C)	Hybrid Striped Bass		White Bass	
	r^2	P^a	r^2	P
9	-0.046	0.610	-0.144	0.107
10	-0.071	0.430	-0.226	0.011*
11	-0.100	0.266	-0.316	<0.001*
12	-0.142	0.112	-0.423	<0.001*
13	-0.174	0.052	-0.482	<0.001*
14	-0.186	0.037*	-0.476	<0.001*
15	-0.195	0.029*	-0.447	<0.001*
16	-0.171	0.057	-0.408	<0.001*
17	-0.129	0.151	-0.350	<0.001*
18	-0.089	0.320	-0.289	0.001*
19	-0.047	0.601	-0.228	0.010*
20	-0.016	0.859	-0.181	0.043*
21	0.007	0.935	-0.142	0.113

[a] Significance probability of the correlation

Table 3. Pearson product-moment correlations between natural logarithms of hybrid striped bass and white bass gill net CPUE rates (number caught/hour) and absolute deviation values from selected photoperiod intervals on each sampling date in the Pensacola Dam tailwater, Oklahoma, January 1988 to July 1989. All correlations are statistically significant ($P = 0.05$).

Photoperiod (minutes)	Hybrid Striped Bass		White Bass	
	r^2	P^a	r^2	P
775	-0.175	0.050	-0.264	0.003
800	-0.212	0.017	-0.326	<0.001
825	-0.222	0.012	-0.312	<0.001
850	-0.189	0.035	-0.271	0.002
875	-0.176	0.049	-0.260	0.003

[a] Significance probability of the correlation

Table 4. Pearson product-moment correlations between natural logarithms of hybrid striped bass and white bass CPUE rates (number caught/hour) and total water discharge (m^3) intervals prior to each sampling date in the Pensacola Dam tailwater, Oklahoma, January 1988 to July 1989. Asterisks denote statistically significant correlations (P = 0.05).

Interval (days)	Hybrid Striped Bass		White Bass	
	r^2	P[a]	r^2	P
1	0.121	0.177	-0.118	0.190
2	0.174	0.051	-0.091	0.311
4	0.205	0.022*	-0.095	0.292
7	0.298	<0.001*	-0.033	0.717
14	0.342	<0.001*	-0.012	0.894
28	0.451	<0.001*	0.156	0.081

[a] Significance probability of the correlation

Table 5. Stepwise multiple-regression models describing the natural logarithms of hybrid striped bass and white bass CPUE rates (number caught/hour) in the Pensacola Dam tailwater, Oklahoma, January 1988 to July 1989. All variables are significant at $P = 0.01$.

Model[a]	R^2	P[b]
$HCPUE = -1.4994 - 0.0935(AT16) + 0.0002(MFLO) - 0.0031(P850) - 0.0897(DIST)$	0.4004	0.0001
$WCPUE = 1.3808 - 0.2613(AT13) + 0.0001(MFLO) - 0.0094(P800) - 0.1563(DIST)$	0.4285	0.0001

Variables within models			
Hybrid Striped Bass	Standardized Partial Regression Coefficients	White Bass	Standardized Partial Regression Coefficients
AT16	0.2757	AT13	0.4774
MFLO	0.6027	MFLO	0.1895
P850	0.2336	P800	0.3628
DIST	0.1784	DIST	0.2249

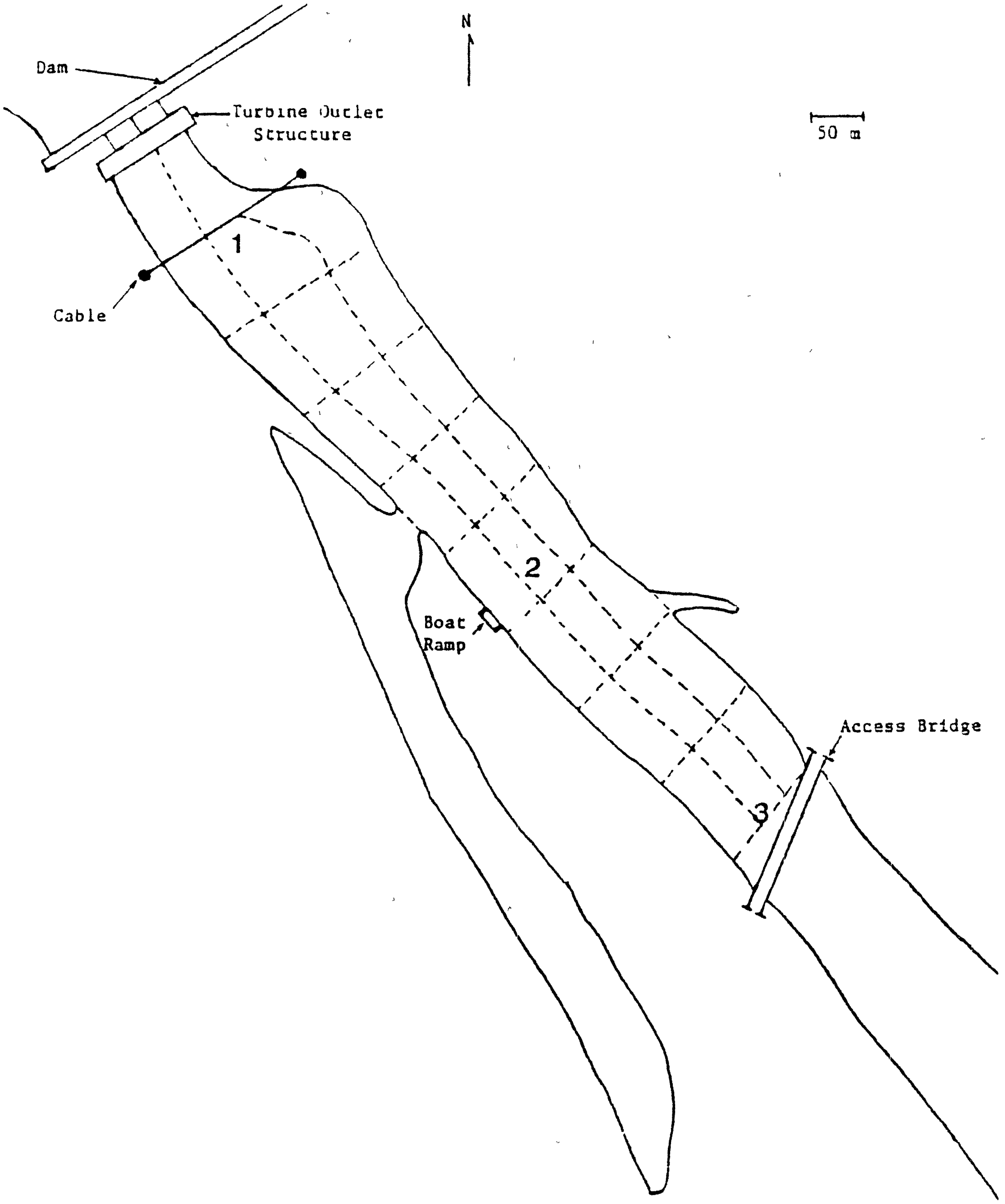
---

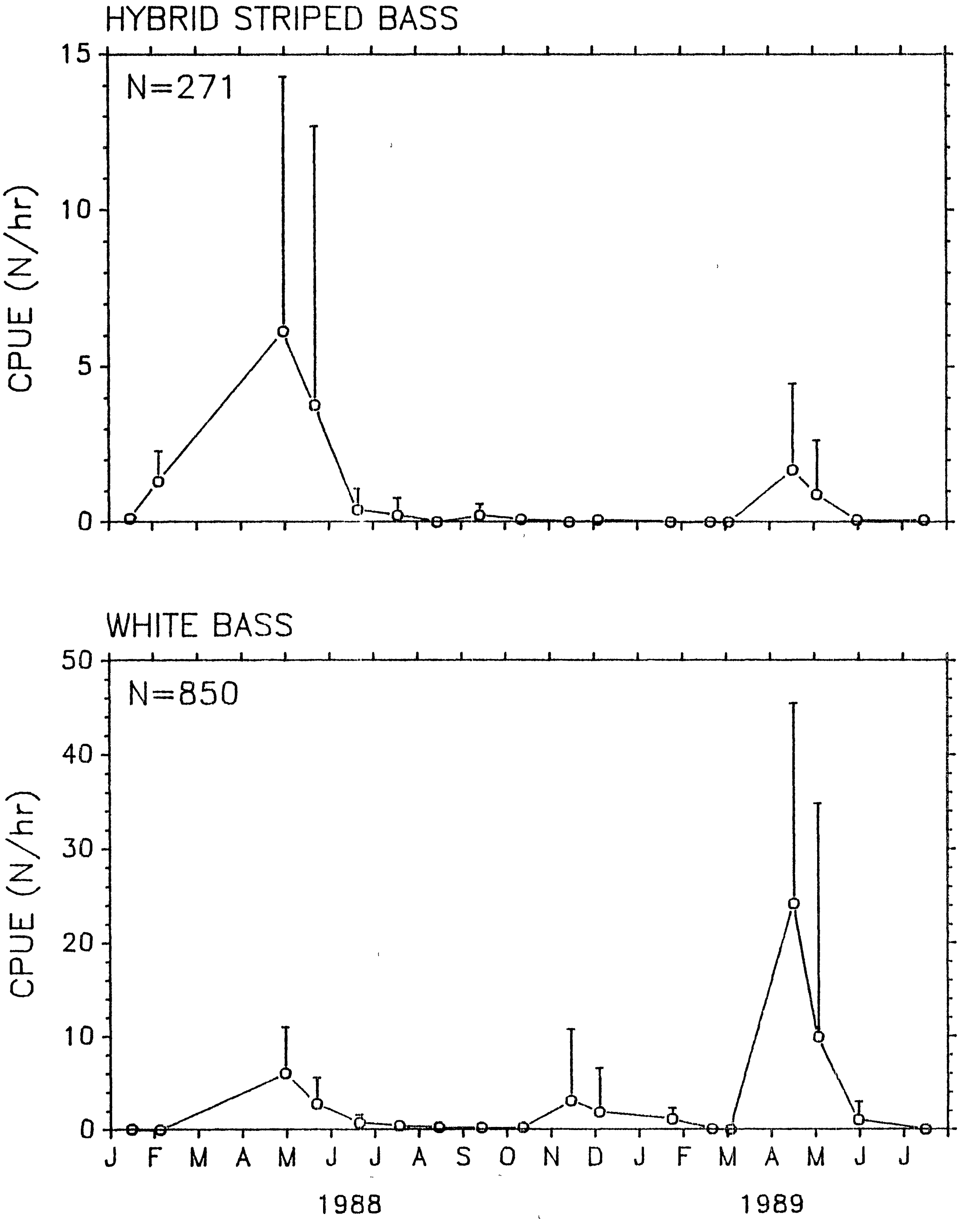
[a] AT13 = absolute temperature deviation values from 13°C; AT16 = absolute temperature deviation values from 16°C; DIST = distance from the dam; HCPUE = hybrid catch-per-unit-effort rate; P800 = absolute photoperiod deviation values from 800 minutes of daylight; P850 = absolute photoperiod deviation values from 850 minutes of daylight; MFLO = total water discharge (m^3) of 28 days prior to each sampling date; WCPUE = white bass catch-per-unit effort.

[b] Probability of a greater F-value.

FIGURE CAPTIONS

1. Sampling stations (dotted lines), water quality stations (numbered 1-3), and general geographical features of the Pensacola Dam tailwater, Grand Lake, Oklahoma.
2. Numeric catch-per-unit-effort (CPUE) rates (+1 SD) for hybrid striped bass and white bass in the Pensacola Dam tailwater, Grand Lake, Oklahoma, January 1988 to July 1989.


N
50 m
Dam
Turbine Outlet Structure
Cable
1
2
3
Boat Ramp
Access Bridge


HYBRID STRIPED BASS
N=271
CPUE (N/hr)
15
10
5
0
WHITE BASS
N=850
CPUE (N/hr)
50
40
30
20
10
0
J
F
M
A
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S
O
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J
J
1988
1989

APPENDIX A

ENVIRONMENTAL PARAMETER VALUES

Table A.1. Photoperiod intervals and means of water temperatures and dissolved oxygen (D.O.) concentrations measured on each sampling date in the Pensacola Dam tailwater, Oklahoma, January 1988 to July 1989.

Date	Photoperiod (min)	Temperature (^{o}C)	D.O. (mg/L)
22 JAN 1988	602	3.34	11.75
4 FEB 1988	633	3.63	12.53
2 MAY 1988	819	15.27	7.06
24 MAY 1988	854	18.27	7.06
23 JUN 1988	873	20.50	6.21
20 JUL 1988	853	22.24	4.30
18 AUG 1988	804	21.07	3.20
16 SEP 1988	741	22.43	5.21
15 OCT 1988	677	18.71	6.51
19 NOV 1988	613	14.53	8.60
9 DEC 1988	580	10.84	9.75
29 JAN 1989	623	7.22	11.83
26 FEB 1989	679	5.24	11.38
11 MAR 1989	707	6.10	10.65
25 APR 1989	805	12.53	10.87
15 MAY 1989	836	15.27	8.48
9 JUN 1989	869	19.60	7.31
25 JUL 1989	847	23.21	4.56

Table A.2. Total water discharge (m^3) into the Pensacola Dam tailwater, Oklahoma, for each of the specified intervals before each sampling date, January 1988 to July 1989.

	Interval					
Date	1 day	2 days	4 days	7 days	14 days	28 days
22 JAN 1988	49,543,650	100,359,532	209,502,358	373,791,548	694,190,820	1,443,980,522
4 FEB 1988	42,619,772	85,851,194	178,944,324	326,523,236	681,989,750	1,370,893,385
2 MAY 1988	58,620,536	117,439,669	235,369,120	470,738,239	818,469,210	1,646,062,087
24 MAY 1988	7,657,858	10,765,040	21,823,672	59,109,856	130,868,634	723,300,588
23 JUN 1988	3,008,900	6,454,575	16,791,601	24,313,850	44,696,718	181,892,821
21 JUL 1988	31,879,198	39,072,202	49,910,640	71,196,060	106,671,760	256,435,877
18 AUG 1988	15,927,366	20,967,362	26,154,154	31,243,082	63,391,406	212,224,468
17 SEP 1988	7,559,994	25,539,398	50,546,756	61,434,126	72,223,632	175,535,308
16 OCT 1988	11,162,046	22,275,562	54,014,597	90,364,043	191,647,479	329,474,483
19 NOV 1988	31,931,158	62,273,704	136,710,800	240,323,706	250,660,731	379,461,037
9 DEC 1988	31,156,668	39,455,406	63,381,010	74,979,831	330,784,810	802,356,993
29 JAN 1989	44,551,123	88,859,593	158,646,647	170,924,897	242,216,401	675,158,198
26 FEB 1989	38,921,569	83,424,162	175,292,655	316,031,497	559,024,388	794,252,377
11 MAR 1989	35,571,252	48,188,613	93,999,338	190,036,866	345,909,801	870,008,699
25 APR 1989	2,474,944	7,036,605	21,595,098	103,947,642	262,295,521	848,752,280
12 MAY 1989	242,642	776,453	1,455,849	14,752,607	48,965,066	228,239,578
9 JUN 1989	52,459,104	90,553,828	143,983,499	212,020,191	448,547,179	713,885,645
25 JUL 1989	21,546,570	44,743,103	103,219,718	268,652,730	386,625,054	557,034,632

APPENDIX B

DATA TRANSFORMATION PROCEDURES

Scatter plots of hybrid and white bass CPUE rates versus water temperature exhibited unimodal distributions with poorly defined peaks (Figures B.1 and B.2, upper graphs). The absence of definite peaks probably rendered traditional statistical analysis inaccurate and subjective; conversion of these curves into linear models would greatly simplify analysis. Temperature data were converted using the following formula:

$$T_t = |T_o - T_s|$$

where T_t was transformed water temperature, T_o was observed water temperature, and T_s was spawning water temperature of hybrids or white bass. Because spawning migrations into the tailwater probably influenced hybrid and white bass CPUE rates, a range of water temperatures encompassing known migration temperatures of hybrids (Williams 1970) and white bass (Webb and Moss 1967; Ruelle 1971; Hamilton and Nelson 1984) were used to transform temperature data. This conversion generated absolute values of deviations from each selected temperature and resulted in the folding of the left-hand arc of the curve onto the right-hand arc, forming a general linear model with the selected temperature as the origin of the x-axis (Figures B.1 and B.2, lower graphs). Natural logarithmic transformation of CPUE rates further linearized these models. Each preferred-temperature-based data set was then tested using correlation analyses; all data sets with significant correlations were used for further analysis. The data set with the strongest significant correlation (i.e., greatest negative r^2 value) generally indicated a peak in the normal distribution at the relevant selected temperature; this indicator was similar to the preference curves produced by Gore and Judy (1981). Photoperiod data were similarly converted (Figures B.3 and B.4), but because recognized ideal photoperiod values do not exist, 'ideal' values were determined, based on goodness-of-fit using correlation analyses, within the range of 550 to 900 min at 25-min intervals. This range encompassed minimum and maximum photoperiod intervals encountered during the sampling period.

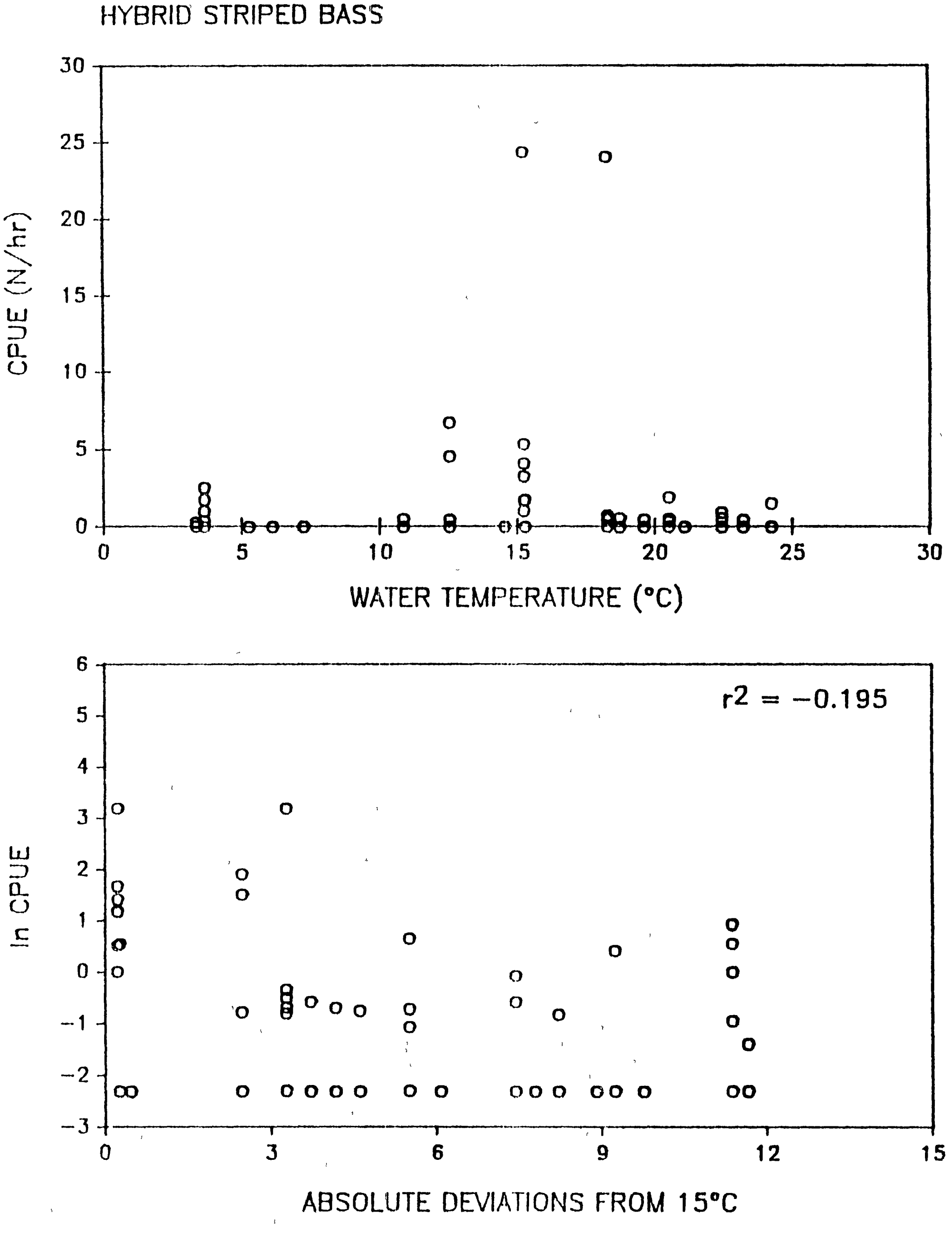

Figure B.1. Relationships between water temperature and hybrid striped bass CPUE rates, before and after transformation.

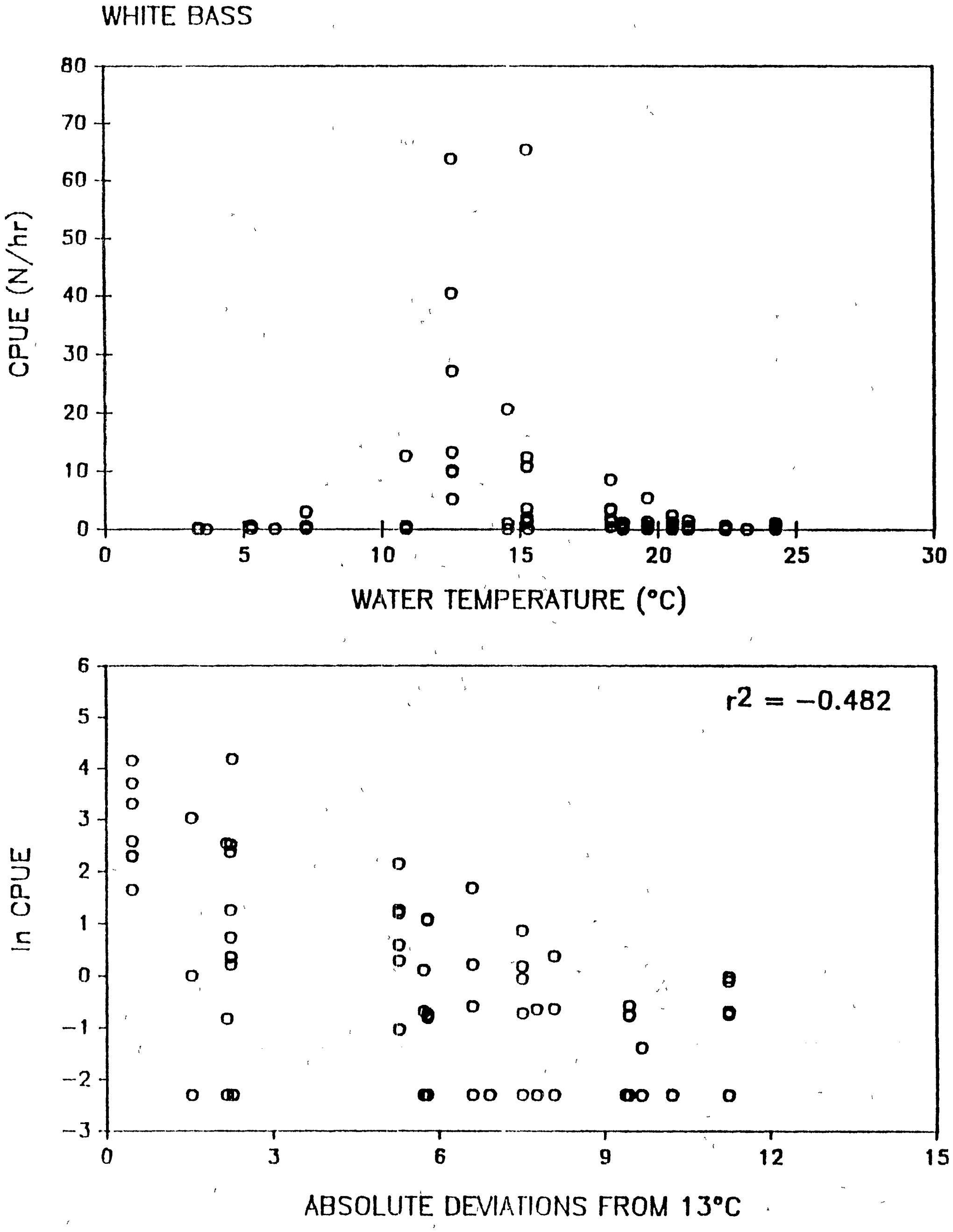

Figure B.2. Relationships between water temperature and white bass CPUE rates, before and after transformation.

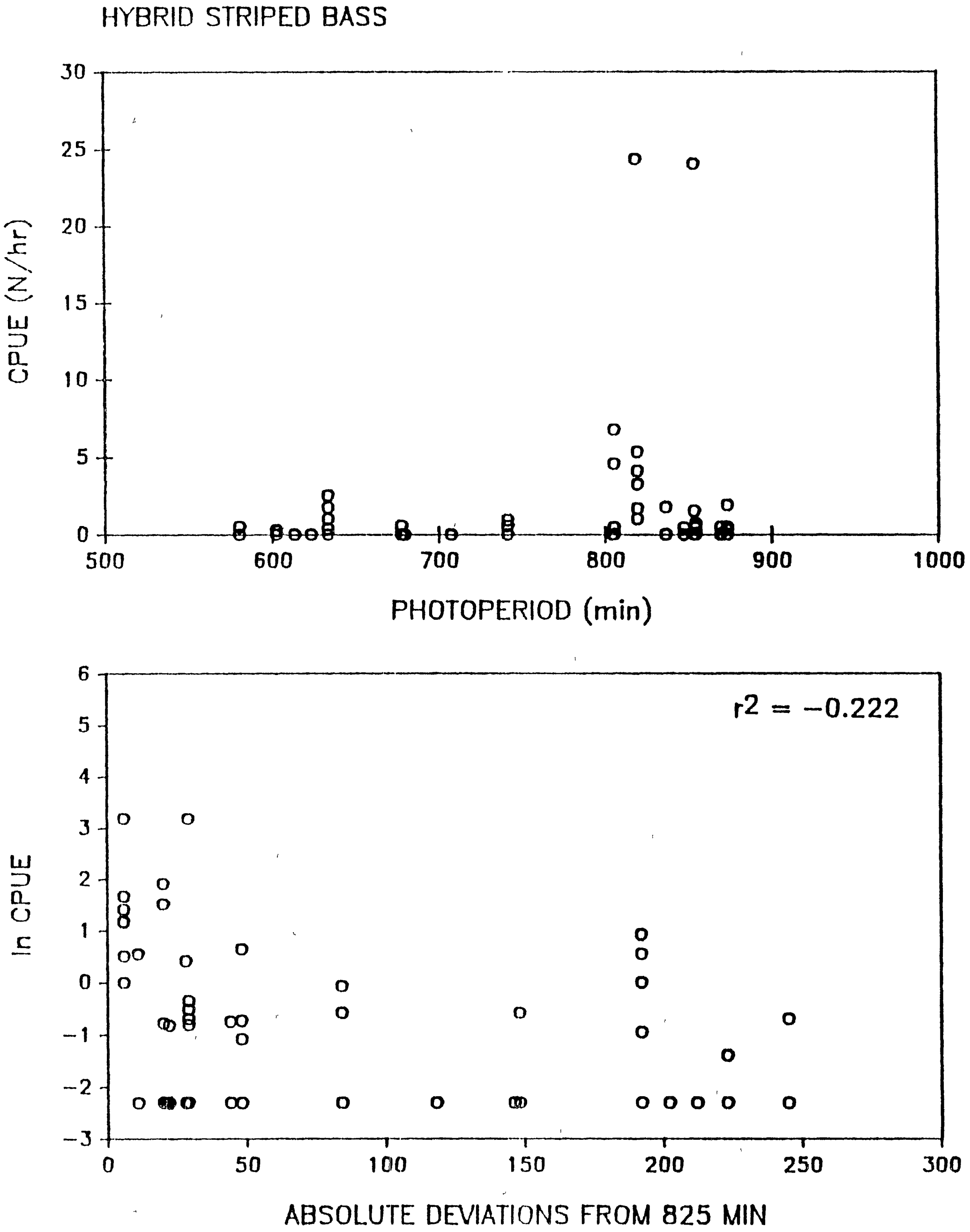

Figure B.3. Relationships between photoperiod and hybrid striped bass CPUE rates, before and after transformation.

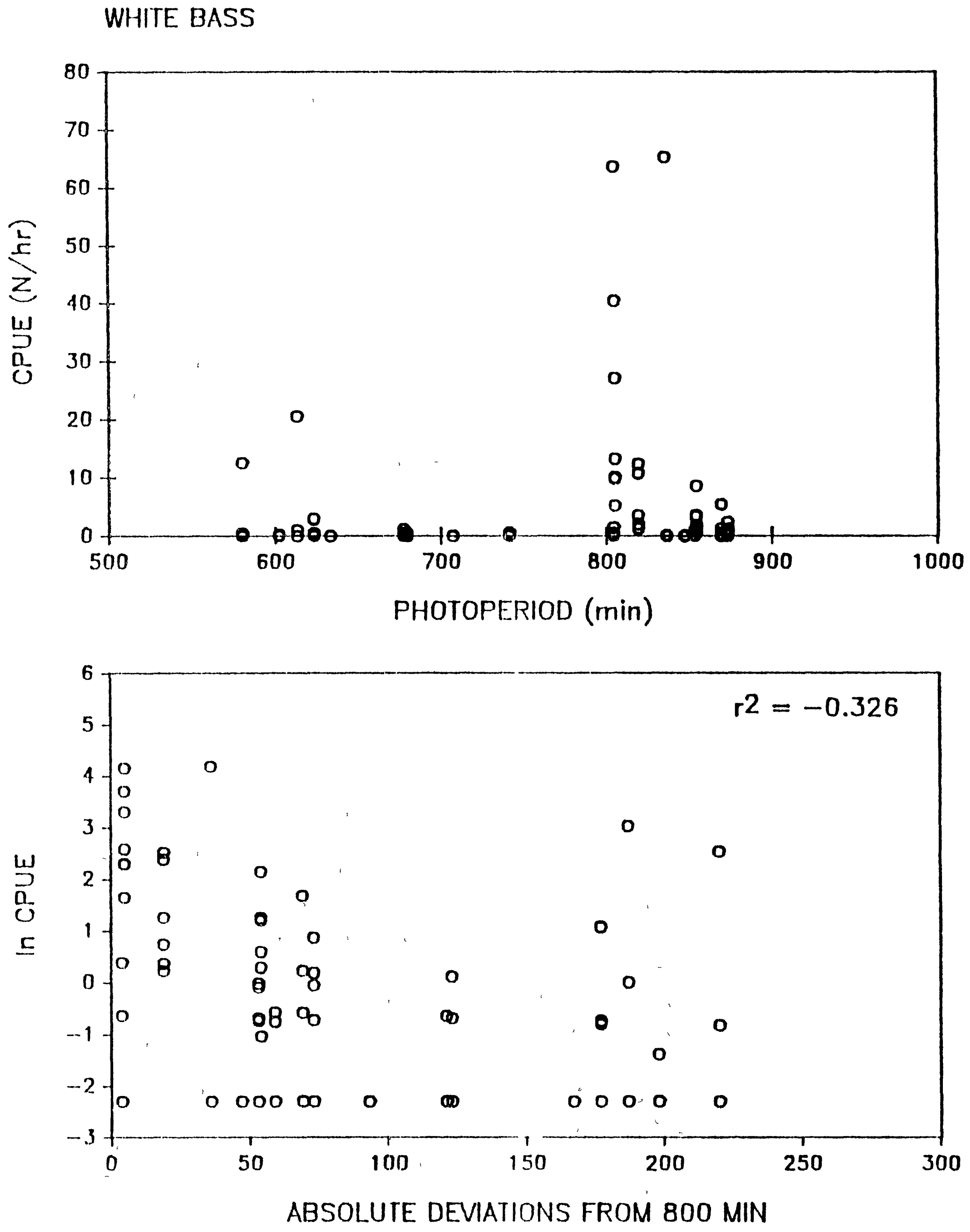

Figure B.4. Relationships between photoperiod and white bass CPUE rates, before and after transformation.

VITA

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Candidate for the Degree of

Master of Science

Thesis: COMPARATIVE INFLUENCES OF ENVIRONMENTAL PARAMETERS ON ABUNDANCES OF HYBRID STRIPED BASS AND WHITE BASS IN THE GRAND LAKE TAILWATER, OKLAHOMA

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